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Application of Remote Sensing and GIS Tools in Delineating Sensitive Water Bodies and Watersheds

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APPLICATION OF REMOTE SENSING AND GIS TOOLS IN DELINEATING SENSITIVE WATER BODIES AND WATERSHEDS

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INTRODUCTION

Since September 11, 2001 security issues have daunted our cities, towns, and communities. Our vulnerability to drinking water cannot be more emphasized when strikes against our citizens are carried out through anthrax contaminated mails and other similar media. Contaminating our drinking water sources could be another easy target for the terrorists when other avenues of terrorism are well guarded. This paper examines and explores various methodologies and tools to keep our water bodies and watersheds secured, monitored and guarded against terrorism, midnight dumping, unintentional spill, or similar damages. The 9/11 incident focused our attention on readdressing EPA's 30 years of protecting the environment and safeguarding human health. After 9/11, further cause for concern was demonstrated by the attacks of anthrax releases directed at several specific targets.

As a part of the EPA's homeland security strategies, the commitment to assess and reduce vulnerabilities is a high priority for the water utility companies. Also, upgrading the capabilities for detection and response for critical infrastructures should be looked into. Also, EPA has identified six specific goals that center around the critical infrastructure protection process. A few of these goals are summarized below (Flory, 2003):

(1) By the end of fiscal year (FY) 2003, all water utility managers will have access to basic information to understand potential water threats, and basic tools to identify security needs. (2) By the end of FY 2003, all large community drinking water utilities shall have identified key vulnerabilities and shall be prepared to respond to any emergency. (3) By the end of FY 2004 all medium community drinking water utilities shall be in similar position. (4) By 2005, unacceptable security risks at water utilities across the country will be significantly reduced through completion of appropriate vulnerability assessment: design of security enhancement plans, development of emergency response plans and implementation of security enhancements.

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Accurate, reliable and comprehensive spatio-temporal information on watersheds and land use practices are key prerequisites for sustainable land and watershed management. Remote sensing offers cost-effective solutions to these needs for both macro and micro level analysis leading to a comprehensive and secured urban environmental management. GIS is best utilized for integration of various data sets to obtain a homogeneous composite watersheds and sub-watersheds which helps in identifying the problem areas and suggest conservation measures. In regional planning, identification of different types of ecologically critical areas and its orientation for future growth is important for a balanced watershed (Dutta 2002). This will be useful to promote environmentally protected zones and other fragile land use forms. Latest information so obtained through remote sensing technology would be of great value in such endeavors.

REMOTE SENSING METHODOLOGIES

The application of new sensor and imagery data and products is a rapidly growing, challenging, and exciting area of technology evolution. The advances in geo-spatial image and data exploitation are being used for more accurate and rapid characterization of the terrain environment and features upon the terrain. Application of these technologies on a wide range of applications include - monitoring of Superfund mining wastes, vegetation classification, construction planning, hyperspectral image analysis, watershed delineation and providing rapid response and recovery support during disasters. Sensor systems used for these purposes include hyperspectral, multispectral, panchromatic, light detection and ranging (LIDAR), and radar.

With the expansion of geo-spatial image and data availability, there is an increased interest in the civil applications of these products for land use planning, watershed analysis/delineation, assessing vegetation conditions, managing natural resources, and decision support tools for disaster response. These expanding applications are an opportunity for tailoring data and product development to meet the needs of a new customer base. Recent meetings, conferences, and workshops have underscored the growing demand for geo-spatial products for a wide range of applications.

This process of interferometric terrain extraction is somewhat complicated. The interferometric synthetic aperture radar (IFSAR) by ERDAS' IMAGINE IFSAR DEM module uses a wizard-based approach to hide this complexity and quickly create high-resolution digital elevation models (DEMs) from synthetic aperture radar (SAR) imagery. The IMAGINE IFSAR DEM module, like ERDAS' IMAGINE StereoSAR DEM module, uses wizards with intelligent defaults derived from the satellite ephemeris information and the image data. The wizard interface is especially useful for novice users, as it steps them through each stage of the process and removes the otherwise complex nature of interferometric processing. Sophisticated techniques, such as adjustment of orbital parameters, interferogram generation, and phase unwrapping are fully automated, requiring minimal user input. With IMAGINE IFSAR DEM, just one good ground control point (GCP) can be used to create a detailed DEM, with a high degree of absolute accuracy. Detail capabilities of IFSAR and LIDAR systems were illustrated in a comparative study (Daniel 2001) of floodplain mapping with IFSAR and LIDAR technologies. IFSAR Consisted of two X-band radar antennae mounted in a LearJet36A (Daniel 2001) as shown on Figure 1.

Figure 1. IFSAR imagery by an Intermap Learjet36 STAR-3i (Courtesy: Daniel 2001)

It utilizes post-processed differential GPS with on-board laser based inertial measurement data. This particular mission was flown at 12,000 m and it acquired a 10 km wide swath. The system is designed to collect <1 m accuracy DEM at a rate of 100 sq km/min.

Figure 2 shows a high-resolution imagery of a floodplain by IFSAR and LIDAR technologies. The comparative analysis of LIDAR and IFSAR system is clearly shown in this figure.

A comparative cost and other characteristics of these two systems, as reported by Daniel (2001) are presented in Table 1 below.

The process of interferometric terrain extraction is somewhat complicated, however the IMAGINE IFSAR DEM module uses a wizard-based approach to hide this complexity and quickly create high-resolution digital elevation models (DEMs) from synthetic aperture radar (SAR) imagery. The IMAGINE IFSAR DEM module, like ERDAS' IMAGINE StereoSAR DEM module, uses wizards with intelligent defaults derived from the satellite ephemeris information and the image data. The wizard interface is especially useful for novice users, as it steps them through each stage of the process and removes the otherwise complex nature of interferometric processing. Sophisticated techniques, such as adjustment of orbital parameters, interferogram generation, and phase unwrapping are fully automated, requiring minimal user input. However, the IMAGINE IFSAR DEM wizard still allows the user to fine-tune all the processing parameters in each step in order to extract the best possible results from a given data set. The use of rigorous sensor modeling techniques minimizes the need for ground control points (GCPs) when creating DEMs. In remote or mountainous areas, the acquisition of multiple GCPs with precise x, y and z values can be expensive, if not impossible. However, with IMAGINE IFSAR DEM, just one good GCP can be used to create a detailed DEM, with a high degree of absolute accuracy.

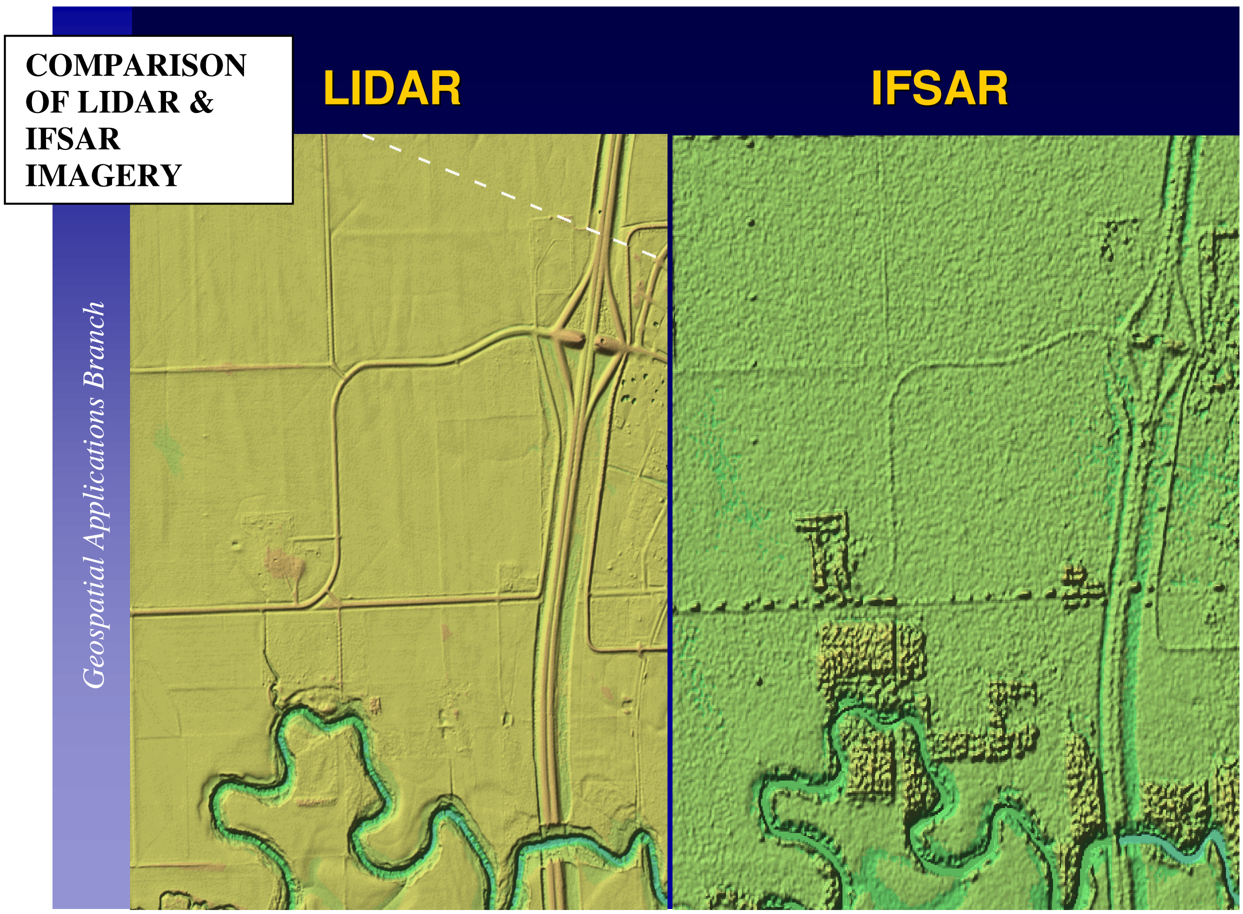

Figure 2. LIDAR and IFSAR Imagery in Mapping a Watershed (Courtesy: Daniel 2001)

Table 1. Interferometric Synthetic Aperture Radar (IFSAR) - Light Detection and Ranging (LIDAR) Comparison

Parameters	IFSAR	LIDAR
1. Sensor Type	Radar	Laser
2. Commercially Available	Single Source	Multi Source
3. DEM Spacing	5 - 10 meters	0.5 - 3 meters
4. Vertical Accuracy	0.6 - 1.5 meters	6 cm and up
5. Typical Cost	$11 - $80 sq. km	$225 - $1500 sq. km
6. Product Delivery	2 - 3 months	2 - 3 weeks

In regional planning, identification of different types of ecologically critical areas and its orientation for future growth is important for a balanced watershed. Also, the remote sensing methodologies can be gainfully used in a rapid response task involving emergencies as illustrated in Figure 4 (Dutta 2003).

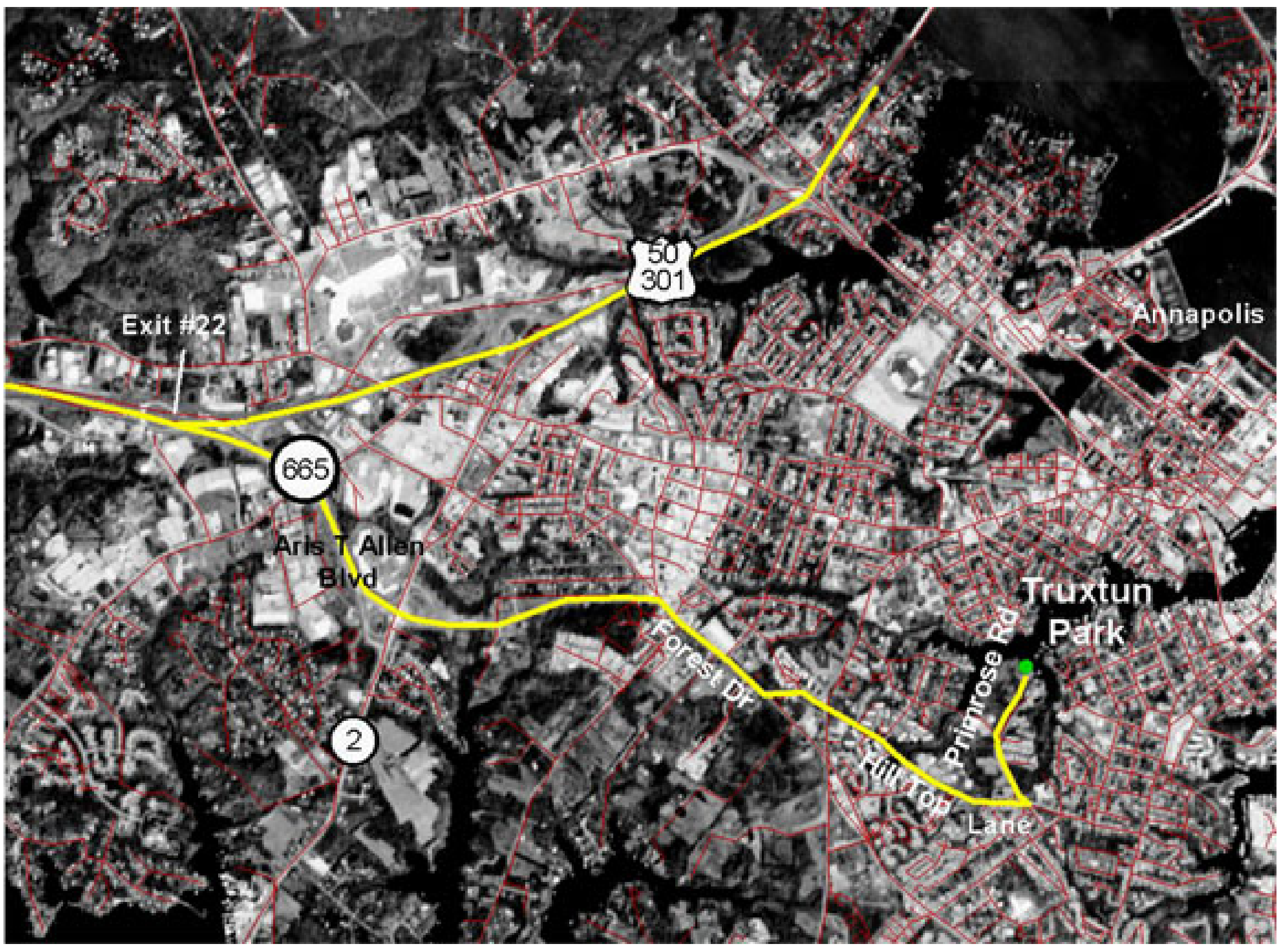

Figure 4. An Overlay of Road System on a Satellite Imagery of Annapolis, MD, for use by Fire and Rescue Quads (Dutta 2003).

Hyperspectral remote sensing (HRS) has recently been used to characterize several water quality parameters for inland water bodies and near shore ocean environments. Optical and thermal frequency bands from a Hyperspectral sensor have demonstrated that the spatial and temporal information needed to track and understand changes and trends in water quality parameters can be measured and used in developing better management practices for improving water quality. The water quality parameters that have been successfully measured include chlorophyll, dissolved organic carbon, and total suspended solids. The information collected from HRS in the future should improve our capability to rapidly assess water bodies and better understand the role and location of point and non-point sources of pollution (Roper, Blanco and Gomez, 2003).

Some case studies undertaken by the authors involve rivers, creeks and watersheds of Loudoun County, Virginia and Northern India.

REAL-TIME REMOTE MONITORING

A few innovative applications of remote monitoring technologies are also currently gaining popularity (http://www.genalert.com/). Governments and agencies can now have water quality data, real-time to provide early warning of oil spills, pollution and many other environmental hazards with our water monitoring system (Genesis 2003).

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